§8. Research on the First Wall Cooling Technique in a Flibe Liquid Blanket System

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In the LHD-type heliotron power reactor FFHR promoted by NIFS, the greatest benefit of the Flibe-blanket system adopting Spectral-shifter [1] which Sagara et al. proposed is that it is basically maintenance-free for 30 years, with emphasis on blanket maintainability. However, against that, heat load on the first wall shoots up higher than ever before. Heat removal of approximately 1MW/m^2 high heat flux, in the single-phase flow condition, is therefore a significant R&D issue which holds the key to the blanket development.

In order to develop a heat transfer promoter for a high Pr number fluid Flibe in accordance with the strict conditions in the reactors, the authors noted Sphere-Packed Pipes (SPP) as a basic heat transfer promoter and have been examining the fundamental heat transfer performance of an SPP in the TNT (Tohoku-NIFS Thermofluid) loop facility which can be regarded as a forced circulation apparatus for high temperature molten salt [2, 3]. The purpose of this research is, first of all, to evaluate the flow structure in a sphere-packed pipe using comparatively large spheres by visualization experiments. After that, this research highlights the correlation between the local heat transfer performance and the flow structure obtained by the PIV, by conducting heat transfer experiments.

To clarify the inside flow structure in a sphere-packed pipe with the sphere of D/2 in diameter (D: pipe diameter), PIV visualization is conducted first by utilizing a matched refractive-index method with NaI solution as the working fluid. As the basic flow structure in the pipe, the following three flows are confirmed: the bypass flow with high flow velocity due to wall effect (see Fig. 1(a)), the complicated wake formed behind the sphere that also works as an impinging jet to the wall (see Fig. 1(b)) and the spouting flow from the central part of pipe. Furthermore, through heat transfer experiment, wall-temperature distribution is measured with thermocouples and an infrared thermography, which clarifies the relation between the flow structure and local heat-transfer performance as shown in Figure 2. The area with high wall-temperature is formed in the stagnation area located around at a contact point between the sphere and the heating wall. However, the heat transfer performance is quite high in the area with a large gap between the upstream and downstream spheres by means of the influence of a separation vortex and the impinging-flow effect, which are both a part of complicated wake. In addition, the high-velocity bypass flow significantly affects the heat transport in the stagnation area. Figure 3 shows the influence of the pumping power on the heat transfer performance. It shows that, under the lower power conditions, the heat transfer coefficient of the SPP flow shows a higher value than that of a swirl flow as well as a circular pipe flow. This indicates that it is effective especially under lower pump-power conditions. However, the heat transfer performance of the SPP flow at high pumping power is much lower than that of the other typical promoters, which suggests that it needs to dramatically enhance the heat transfer performance at the contact point by using fin-effect from the heating wall to the sphere and changing the packing structure etc. in a case of using the sphere of D/2 in diameter. For reference, heat transfer performances for the different sizes of sphere, D/d=3.0 and 1.4, are also shown in the same figure by use of Fand's correlation. The utilization of smaller size of sphere is much more effective than that of D/2 size of sphere in the case without the fin-effect. This indicates high potential for the heat transfer performance of the SPP flow, so that it is evident that the SPP's heat transfer performance dominates other heat transfer promoters, especially when considering all pressure drops of coolant circulating system

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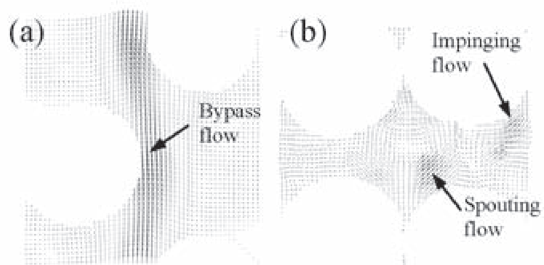

Fig. 1 Flow structures in Sphere-Packed Pipe

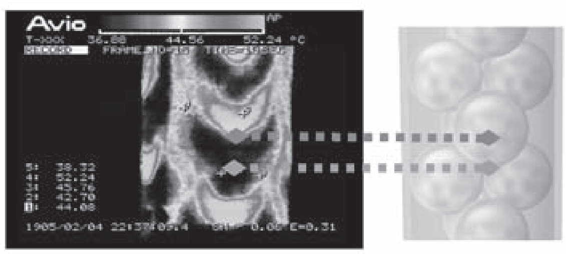

Fig. 2 Temperature distribution of wall

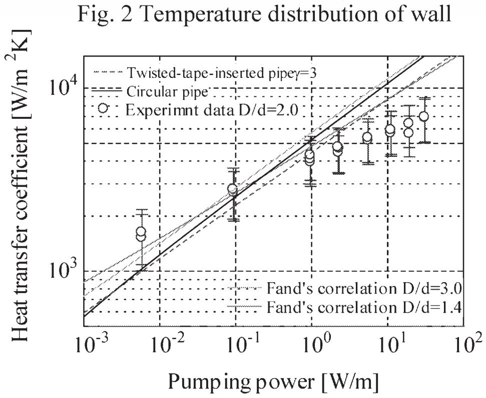

Fig. 3 Heat transfer performance of SPP

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